A COMPARATIVE REVIEW OF ENERGY AGGREGATION POLICIES FOR PROSUMERISATION OF GREEN ENERGY IN THE CONSTRUCTION PHASE IN UK AND UGANDA

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Prosumerism has emerged as a promising strategy for generating green energy for use during the construction phase, contributing excess electricity to the grid, and reducing heavy reliance on traditional power grids, thus playing an immense role in the future energy scenario. However, successful implementation of the concept is contingent upon supportive regulatory frameworks and policies. Using secondary qualitative data, this paper presents a comprehensive comparative review of existing energy aggregation policies and regulations in Uganda and the United Kingdom, seeking support and ideas for the deployment of microgrids on construction sites within the context of Net Zero Carbon Construction (NZCC). We analyse the different regulatory approaches, examining their efficacy, strengths, limitations, and opportunities for prosumerisation of the construction phase. Furthermore, we offer insights into best practices that could be adopted to attract the construction sector players towards green energy generation and use on construction sites. Emphasis is put on the urgent need for proactive policy interventions that incentivise, standardise, and streamline the integration of prosumerism within NZCC frameworks to advance the global agenda towards a low carbon built environment.

Keywords: energy aggregation; energy policy; green energy; net-zero; construction; prosumer

INTRODUCTION

The construction industry, despite its significant impact on global energy consumption and GHG emissions, holds immense potential to contribute to the global decarbonisation goals. It significantly impacts energy consumption, greenhouse gas (GHG) emissions, and other sustainability indicators, including global warming (IEA 2020). Globally, construction and use of the built environment account for up to 40 percent of global energy consumption and 39 percent of GHG emissions (Sizirici *et al.,* 2021; Crawford 2022). These emissions mainly stem from the sector's heavy reliance on fossil fuels for powering site equipment and the manufacture and transportation of building materials (Sizirici *et al.,* 2021). Nonetheless, the focus has been mainly on operational carbon reduction, overlooking the embodied carbon emissions related to the construction process (Kibwami and Tutesigensi 2016). By

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addressing these embodied emissions, the construction sector will not only bridge the gap between its actual performance and decarbonisation goals but also play a significant role in achieving the global carbon goals.

As underscored by the recent COP28 conference, the transition of all sectors to clean energy is critical in limiting global warming to 1.5oC, so governments, industry, and international organisations must implement the right policies, regulations, and investments to facilitate this transition (United Nations 2023). The successful contribution of the construction sector to this global call necessitates a comprehensive transformation of all activities by integrating renewable energy and adopting sustainable practices throughout the building life cycle from design, construction, operation, and end-of-life (Sizirici *et al.,* 2021). Given their significant control over site-based activities, construction organisations have a critical role in reducing carbon emissions generated during the construction phase of building and infrastructure projects. By investing in their own distributed green energy resources such as solar and wind, and potentially selling all the excess energy back to the grid through prosumerisation, the construction sites will not only aid the transition to zero carbon through the reduction of own and societal greenhouse gas emissions (Hu and Chuang 2023) but also reduce reliance on traditional power grids thus aiding the adaptability to climate change.

However, transitioning to the generation and use of green energy requires a complete transformation of the entire energy sector, affecting not only how electricity is generated and transported but also the restructuring of business operations to allow for the decentralisation of the energy market (Hu and Chuang 2023), which are all hinged on supportive prosumer aggregation policies and regulatory environments. This paper, therefore, seeks to comprehensively review and compare the existing energy aggregation policies in Uganda and the United Kingdom to determine their efficacy, strength, limitations and opportunities for the prosumerisation of the construction phase of projects for Net Zero Carbon Construction (NZCC).

LITERATURE REVIEW

Efforts to mitigate carbon emissions in the built environment are crucial as the construction of buildings and infrastructure accounts for about 20 percent of the global carbon emissions, totalling up to 7 Gt CO2e (WSP 2020). Recent studies have quantified these emissions across various countries, revealing significant disparities between developed and developing nations (Sizirici *et al.,* 2021; Crawford 2022; Weigert *et al.,* 2022; Kanafani *et al.,* 2023). For instance, Crawford (2022) compared emission intensity across thirty-four countries and found emission intensities ranging from 0.165 kgCO2e/Euro to 2.05 kgCO2e/Euro with developing countries like China and India contribute significantly more to construction emissions than developed countries like the UK and least-developed African countries like Uganda.

The urgency to mitigate global GHG emissions has popularised the terms zero and net zero. The idea of zero emissions is to eliminate GHG emissions, while net zero involves balancing the amount emitted with equivalent removals from the atmosphere, often through offsetting or carbon capture (Green and Reyes 2023). The current research, however, extends the net zero concepts to encompass collective efforts by individuals, organisations, industries, and communities to achieve net zero carbon emissions, with a particular focus on construction sites.

Most research on NZCC focuses broadly and emphasizes the strategies for the construction sector to address both embodied carbon from materials and processes and operational emissions from buildings. Suggested measures include design efficiency, low-carbon cement and concrete use, minimising transport impacts, and reuse and recycling (Miller *et al.,* 2016; Gálvez-Martos *et al.,* 2018). These measures have been categorised into supply-side technologies, such as the use of cement admixtures and alternative chemistries, novel chemical catalysts and separation technologies, and demand-side measures like material-efficient design, waste reduction, substituting low-carbon for high-carbon materials, and circular economy interventions. (Rissman *et al.,* 2020). Karlsson *et al.,* (2020) highlight that implementing the current best practices and technologies in road construction can significantly reduce emissions, potentially achieving net zero by 2025, with key enablers including sustainable biofuels and electrified heavy transport and construction equipment.

Policy interventions, including high-value policies for carbon capture and trading and emission standards, have also been recommended (Rissman *et al.,* 2020; Sirizi *et al.,* 2021). The House of Commons Environmental Audit Committee (2021) emphasizes whole life cycle carbon assessments and progressively tighter carbon limits for new building projects to reduce the UK's construction sector carbon footprint. This move could indirectly promote and incentivise prosumerism, where the sites become energy consumers and producers to meet the ambitious industrial decarbonisation target of a 90 percent carbon reduction by 2050 (DBEIS 2021). This shift from centralised fossil-based fuel systems to decentralised Renewable Energy (RE) systems has led to the concept of energy prosumers - actors who produce and consume RE (Brown *et al.,* 2019) and holds immense potential in the quest for NZCC.

Despite its potential, there is a noticeable gap in the literature on the direct relationship between prosumerisation or energy aggregation policies and achieving NZCC. Some studies have examined RE prosumerisation across different sectors (Parkes and Spataru 2017; Carfora *et al.,* 2018; Brown *et al.,* 2019; Inês *et al.,* 2020). Inês *et al.,* (2020) identified the main challenges and opportunities for collective RE prosumption in Europe. However, no study has yet integrated the prosumer phenomenon into the construction sector to achieve NZCC. Our study aims to promote the implementation of on-site microgrids and prosumerisation during the construction phase. We note that the succesful adoption of the concept depends significantly on existing country policies and regulations, as strategies that work well in one region may require adjustments to fit the circumstances elsewhere.

METHOD

The research adopted a multiple case study design to comprehensively assess and compare the existing legal frameworks of Uganda and the UK, chosen for their comparability, data availability, and relevance to the broader research questions. The UK, a global leader in energy transition with comprehensive and effective policies and regulatory frameworks that support RE adoption and present a clear opportunity for collective prosumers, with advanced infrastructure and technological capabilities and low emission-intensive construction, serves as a benchmark for best practices in energy policy and innovation (Inês *et al.,* 2020; Sizirici *et al.,* 2021). With its unique but untapped RE potential, Uganda can learn from the UK to enhance its RE strategies and promote prosumerism in all sectors, including construction. This comparative approach offers a more expansive view on how different regulatory environments affect energy aggregation policies, with cross-regional and transnational studies being crucial in identifying contextual influences and improving the validity and transferability of research findings (De Laurentis and Pearson, 2021).

The data used for this review was sourced from common databases, including Scopus, Web of Science, and Google Scholar, and grey literature, including policy documents, regulations codes, and reports produced by government energy departments and construction regulatory bodies in Uganda and the United Kingdom, based on a variety of relevant search strings. The search terms included UK, Uganda, energy aggregation, energy policy, green energy, and prosumer. Only literature published in English from 2015 to date was considered.

The data collected was sorted using Endnote 21.1 and Covidence software and extracted using NVIVO 14. Based on the PRISMA flow diagram in Figure 1, the review was systematically done and documented for consistency, reliability, and validity. In NVIVO, the study adopted a deductive thematic analysis where data was coded under predefined themes based on the current research objectives, clustered per country, Uganda or the UK. After coding, the themes were reviewed and refined to reflect the concepts captured within the codes, ensuring the robustness and credibility of the research findings.

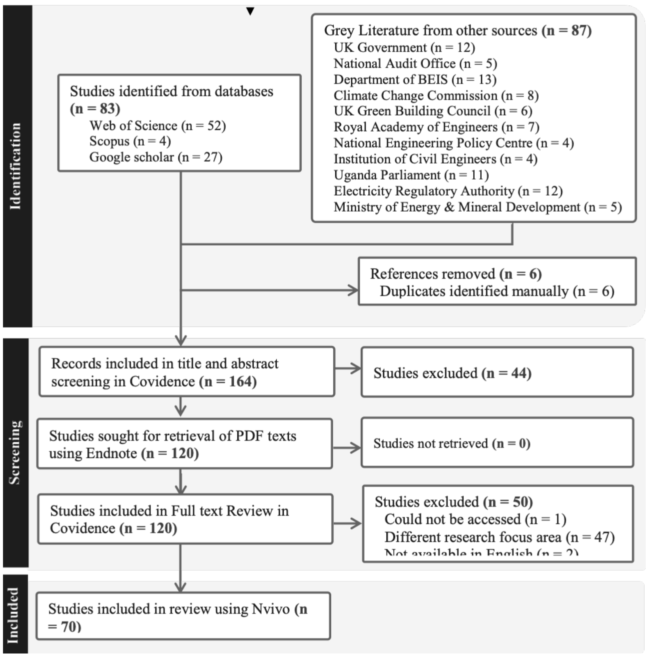

Figure 1: Flow diagram of the screening process for the systematic review of RE policies

FINDINGS AND DISCUSSION

Study Characteristics

Of the 70 records included in the study, the majority 43 percent were journal articles, with 57 percent of these studies conducted in the UK. 30 percent of the records were reports obtained from different government energy and construction regulating bodies in both Uganda and the UK, and the remaining 27 percent policies Acts, and regulations, 80 per cent of which were from Uganda.

RE Potential and Adoption

Despite having a renewable resource potential of up to 160 TWh per annum (CCC 2015), the UK's energy system remains predominantly centralised with a significant reliance on fossil fuels (Mirzania *et al.,* 2019). In 2014, the UK's total generation was

298 TWh, consisting mainly of coal (32%), gas (29%), renewables (20%), and nuclear (19%). Of the renewables, wind contributed 10.4% and solar PV only 1.3%, with no geothermal production (CCC 2015). As a market leader in offshore wind, the UK had an installed capacity of 5 GW, generating 13 TWh in 2014 (CCC 2015). By 2022, the share of RE in the UK energy mix had grown to 46% (IRENA 2023).

This growth is depicted in a recent study by Mirzania *et al.,* (2019), who found solar PV to be the most common renewable source, making up 50% of the UK RE mix, mainly in England, followed by hydro (22%) Dominant in Scotland and Wales, and onshore wind (11%). A recent CCC report (2023) Confirmed solar as the leading energy source, achieving an all-time high of 4.1 GW capacity in 2022, mainly deployed on residential and commercial rooftops. However, Westacott and Candelise (2016) Noted that the non-domestic market was the smallest segment, with only 350 MWp capacity spread over 12,000 installations in 2013, ranging from 2 kW to 5 MWp in 2013, with higher deployments in the south than in the north due to higher solar radiation.

Uganda, on the other hand, has a substantial RE potential of over 7500 MW, including 4,500 MW from hydro, 450 MW from geothermal, 300 MW from wind and peat, and 1650 MW from cogeneration, making it one of Sub-saharan Africa's most extensive RE resource base (Twinomuhangi *et al.,* 2022). Unlike the UK, Uganda's current energy mix is dominated by renewables, providing over 90% of the country's energy (Uganda Government 2023). As of March 2022, hydropower accounted for 89.5% of Uganda's electricity supply, with an installed capacity of 1,072.97 MW, followed by cogeneration 8% with 11.7 MW, and solar 4.6% with 60.9 MW (ERA 2023). Despite the potential, Uganda faces significant challenges in harnessing its renewable energy resources. For example, despite having almost twice the solar energy potential of the UK, with an average practical potential of 4.462 kWh/kWp compared to 2.613 kWh/kWp and mean solar radiation of 5.1 kWh/m2 per day available year-round, Uganda's installed capacity is still less than 1% of its practical potential (Uganda Government 2017; World Bank Group 2024).

In addition, although Uganda's mean wind density is lower than that in the UK, with wind speeds of only 5.12m/s compared to 10.18m/s, it is still adequate for small-scale electricity generation with potential domestic or industrial targets ranging from 2.5 kV to 10 Kv (Uganda Government 2017; World Bank Group 2024). However, to date, wind power installations have yet to be implemented due to the perceived technical and financial risks associated with Solar and wind technologies (Uganda Government 2017; Twinomuhangi *et al.,* 2022). Furthermore, the government's growing interest in oil and gas development for power generation diverts attention from RE generation, which is detrimental to the country as it strives to meet its 2050 Net Zero targets.

Existing Renewable Energy Policies Pertinent to Energy Aggregation

Both Uganda and the UK have robust policies governing RE generation, including central government policies, market reforms, and support schemes, as summarised in Tables 1 and 2. Both countries utilise comprehensive policy frameworks integrating investment and promotion policies with support schemes like Feed-in-Tarriffs (FiT) And auctions. However, as shown in Table 1, the UK also employs additional policies such as the CfD and RO, which encourage decentralised green energy production and consumption, with some managed by the local authorities.

Table 1: Existing RE policies in the UK and their efficacy

Policy and year	Efficacy
Electricity Act (1989)	provides the legal framework for regulation of the energy sector.
Energy Act (2023)	legal basis to set up feed-in-tariffs for small scale RE generation.
Electricity market reform (2014)	market-based support policy for quotas, tradable certificates and contracts.
Feed in Tariffs order (2012)	incentiveses individual and collective self-consumption with capacity below 5MWp.
Contracts for Difference (CfD) (2014)	contractual mechanism that incentives and protects RE generators from volatile wholesale prices.
Renewables Obligation (Amendment) (Energy Intensive Industries) Order (2017)	mandates electricity suppliers to produce a certain number of renewables obligation certificates with respect to the electricity they supply to customers.
Planning Policy Statement 22 | (PPS) (2022)	regulates onshore wind generation, hydro, solar PV, passive solar, biomass and energy crops.
Energy white paper (2023)	sets out long-term policies and commitments for the achievement of Net zero, including energy transition to green energy.
Clean Growth Strategy (2017)	mandate issued by the central government to local authorities to support energy transition and carbon reduction across all sectors.

Source: (Westacott and Candelise 2016; Parkes and Spataru 2017; DBEIS 2020; 2022; Inês et al., 2020; Gudde et al., 2021; DLUHC 2022; HM government 2023)

Table 2: Existing RE policies in Uganda and their efficacy

Policy and year	Efficacy
Electricity Act (1999)	provides the legal framework for regulation of the energy sector.
Electricity Amendment Act (2022)	revised the capacity under the REFiT upwards from a maximum of 20MW to 50MW
Electricity (Royalties) Regulations (2022)	governs the issuance of generation licenses for RE projects.
Electricity (Supply of Electricity in Bulk to Specified Consumers) Regulations (2022)	prescribes the terms for the sale and purchase of electrical energy in bulk between a licensed generator, transmitter, distributor and an eligible customer
Renewable Energy Feed in Tariffs (REFiT) (2010, 2023)	provides a framework for setting tariffs for small scale RE projects.
Renewable Energy Policy (2023)	legal basis to set up feed-in-tariffs for small scale RE generation.
Revised energy policy framework (2020)	focuses on increasing the use of RE and ensuring access for all, especially in rural areas.
The Electricity (Approval and Verification of Investments) Regulations (2020)	sets out the process, principles and standards for approving and verifying investments in the electricity supply industry.

Source: (Uganda Government 1999, 2017, 2020, 2022; Bößner et al., 2020; Mabea 2020)

Interestingly, as depicted in Table 2, some of Uganda's policies mirror those of the UK, including the Electricity Act and REFiT which is like the UK's FiT, designed to incentivise RE deployment through premium tariff payments for each kWh of generated power (Westacott and Candelise 2016; Parkes and Spataru 2017; Mabea 2020; ERA 2023). A notable difference is in the capacity considerations; while the UK's FiT applies to capacities below 5MWp, Uganda's REFiT phase VI has been recently revised to cover up to 50MW (ERA 2023).

Despite its rapid decentralisation of electricity compared to Uganda, the UK similarly lacks fully supportive RE policies for prosumer models beyond simple subsidy regimes like the FiT. This policy gap has been highlighted as the main barrier to collective energy prosumption by Inês *et al.,* (2020), who, amidst acknowledging the significant opportunity for prosumerisation within the UK policies, advocate for regulatory frameworks to facilitate prosumerisation. In addition to new regulations, Brown *et al.,* (2019) Recommend adaptive market designs to support prosumer business models, which could apply to the construction industry.

Amidst the greater emphasis on reducing carbon emissions and achieving NZCC over Uganda, the UK lacks specific policies incentivising energy aggregation on construction sites. Current efforts focus more on RE procurement strategies and commitments by individual companies and developers. For example, the PPS22 encourages incorporating RE in new developments but falls short of comprehensive incentives, policies, or road maps for RE adoption across the construction sector (DBEIS 2022). This gap is underscored by the House of Commons Environmental Audit Committee report (2022), which overlooks RE adoption and prosumerisation to reduce embodied carbon emissions from construction. Similarly, Sizirici *et al.,* (2021) Discuss economic instruments to mitigate GHG emissions but do not address energy aggregation policies specific to construction. Therefore, although prosumerisation of construction sites is pivotal for transitioning to decentralised and sustainable energy systems and reducing on-site emissions on site, aiding the achievement of NZCC, energy aggregation policies tailored to the construction industry are largely lacking in both Uganda and the UK governments, both in government initiatives and literature. This legislative gap indicates that both countries still need to realise the untapped potential of prosumerism and energy aggregation fully. Therefore, it is imperative to develop regulatory frameworks that mainstream prosumers, thereby hastening the transition to more sustainable systems and the attainment of NZCC.

Policy Strengths and Limitations

Despite the lack of specific legislation for prosumerisation during the construction phase, both UK and Uganda have incentives for self-production and supply of green energy. In Uganda, the existing RE targets and financing mechanisms set in the Renewable Energy Policy (2017) And the REFiT serve as a foundation for construction contractors to invest in green energy. The REFiT phase V review in June 2023 increased the capacity limit from 20 MW to 50 MW for phase VI and introduced a linear tariff for hydro, Solar PV, and wind projects (5MW to 50 MW (ERA 2023). The contractors can leverage the 20-year contracts that offer stable and predictable returns for energy supplied to the grid. Additionally, Uganda's electricity market reforms, including quotas, tradable certificates, independent power producer (IPP) Agreements and public-private partnerships (PPPs), support a wide range of RE technologies and power decentralisation across diverse areas (Bößner *et al.,* 2020; ERA, 2023), benefitting the construction industry with widely dispersed sites.

Amidst these strengths, some limitations hinder RE adoption in Uganda's construction sector. Unlike UK policies, Uganda's RE policies are not decentralised, limiting implementation at local levels (Twinomuhangi *et al.,* 2022). Furthermore, these policies do not address socio-economic factors such as land availability and high initial costs related to installation, grid connection, distribution, transmission, storage, and other dependency costs. Given the perceived complexity of these technologies (Uganda Government 2017), streamlined implementation plans are necessary for the successful prosumerisation of RE in the construction sector.

Opportunities for the Prosumerisation of Uganda's Construction Sector

The literature highlights several opportunities for prosumerisation of green energy in Uganda's construction industry during the construction phase of projects including: 1) The significant untapped potential for solar, wind and geothermal energy across the country 2) The ambitious target to achieve over 60% electricity acess by 2025, addressing a 165 MW electricity deficit and increasing demand for energy security, 3) The need to diversify the energy mix to mitigate climate effects and reduce reliance on hydropower, 4) The supportive RE policies and promotion strategies including the 2017 RE policy and REFiT phase VI (2023), focusing on increasing RE use, 5) Strong government incentives and programs promoting RE, and, 6) The 2017 RE policy's decentralisation plan, creating a new RE department in the Ministry of Energy and Mineral Devlopment and establishing National Energy Comitees at various government levels, bridging the gap between policymakers and prospective prosumers (Uganda Government 2017; Adams and Asante 2019; Twinomuhangi *et al.,* 2022).

CONCLUSIONS

The paper examines and compares the energy aggregation policies in Uganda and the UK, focusing on their efficacy, strengths, limitations, and opportunities to support the prosumerisation of the construction phase within the context of NZCC. Despite the absence of specific legislation for prosumerisation in construction, both countries have provisions that incentivise the self-production and supply of green energy. With its RE Policy (2023) And the REFiT, Uganda can learn from the UK's CfD and RO policies to strengthen its foundation for green energy investments in construction. Decentralising RE policies will enable Ugandan construction organisations to play a critical role in the NZCC drive, leveraging the untapped RE potential, meeting the growing electricity demand, and diversifying the energy mix for climate resilience and adaptability. For a successful transition to green energy generation and prosumerisation of the sector, the Ugandan government and construction regulatory bodies need to establish robust regulatory frameworks, develop infrastructure, enhance supply chains, raise awareness, and coordinate all sector stakeholders. Policymakers, industry leaders, and practitioners can use these findings to create proactive policy interventions that incentivise, standardise, and streamline prosumer integration within NZCC frameworks, ultimately advancing the global agenda towards a low carbon built environment.

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